Distribution and Abundance of Benthic Macroalgae in the Swan-Canning Estuary, South-Western Australia

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Abstract

The macroalgal communities of the Swan-Canning Estuary were investigated between August 1995 and May 1997. Thirty-six macroalgal species were recorded, predominantly of the division Chlorophyta. Macroalgal species number was highest (15 to 22 species) in the lower, more marine reaches of the estuary, and in the seasons of hydrological change when freshwater flows were commencing or abating (*i.e.* spring and autumn). Macroalgal biomass was patchy both spatially and temporally: highest biomass was in the lower estuarine reaches (629 g.m^{-2} dwt), where mixed soft and hard substrata were present in spring (November 1996) after winter freshwater pulses had subsided. Macroalgal biomass was generally dominated by rhodophytes, especially the species *Gracilaria comosa*, although high biomass was also attributable to the phaeophyte *Cystoseira trinodis* at sites characterised by a hard substratum in the lower reaches of the estuary.

Keywords: Swan-Canning Estuary, benthic macroalgae, biomass, species number, *Gracilaria comosa*

(Manuscript received June 2003; accepted November 2003)

Introduction

The Swan-Canning Estuary is a large south-western Australian system that stretches more than 50 km inland from the coast at Fremantle. The system contains extensive areas of shallow sand-flats. Two rivers discharge into the system: the Swan-Avon River to the east, and the Canning River to the south, with catchment areas of approximately 119 000 km^2 and 20 000 km^2, respectively (Thurlow *et. al.* 1986). The suburban and industrial development of Perth city occupy a large proportion of the estuary's banks (Hodgkin 1987).

The Swan-Canning Estuary is a highly seasonal system, where the main influence is large freshwater pulses driven through the waterbody in winter. With the onset and dissipation of freshwater flows, the physico-chemical environment of the estuary changes. During winter (July to September), relatively high and sporadic rainfall events (over 100 mm per month) generate highly variable and pulsing river flows (>100 m^3.s^{-1}). Associated with the pulses are low salinities throughout most of the estuary (approximately 5 units at the surface although bottom waters near the mouth are up to 32 units), low temperatures (13–14 °C) and high light attenuation (Secchi disk depth 35 to 70% of the water column). The freshwater pulses lead to an elevation of nutrient concentrations; dissolved inorganic nitrogen concentrations are commonly between 0.6 and 1.65 mg.L^{-1} in fresher surface waters, and 0.15 to 1.25 mg.L^{-1} in the more marine bottom waters (Astill 2000). As rains and the freshwater input to the system subside, there is a gradual transition in the estuary's physico-chemical environment, largely brought about by marine waters penetrating into the estuary as a salt wedge, reaching some 55 km upstream from the estuary mouth by autumn (Astill 2000). At this time, salinity, temperature, and light penetration increase in all regions of the estuary (20 to 35, and 19 to 21 °C, 40 to 80%, respectively), and dissolved inorganic nitrogen concentrations decrease (<0.3 mg.L^{-1} throughout the system).

Macroalgae are a conspicuous biological component of the Swan-Canning Estuary. Allender (1981) recorded 29 species when he surveyed the estuary in the summer of 1968 between the junction of the Swan and Helena Rivers and the mouth of the estuary. Allender proposed that changes in the assemblages within the estuary could be spatially defined by the seasonal salinity regimes. Many of the species present were typical of eutrophic estuaries and have been recorded in the estuary since at least the 1970s (Allender 1981).

This study investigated the populations of attached and unattached macroalgae present in the Swan-Canning Estuary, almost thirty years after Allender's (1981) preliminary and qualitative investigations of this biological component of the Swan-Canning Estuary. The primary aims of this study were to investigate the macroalgal species now present in the system in comparison to Allender's findings, and to quantitatively describe the temporal and spatial variation within the macroalgal populations present in the estuary.

During the study, macroalgal assemblages were surveyed seasonally over two years (August 1995 to May 1997). Assemblages were investigated for a number of characteristics including species numbers, temporal presence and absence, and macroalgal biomass.

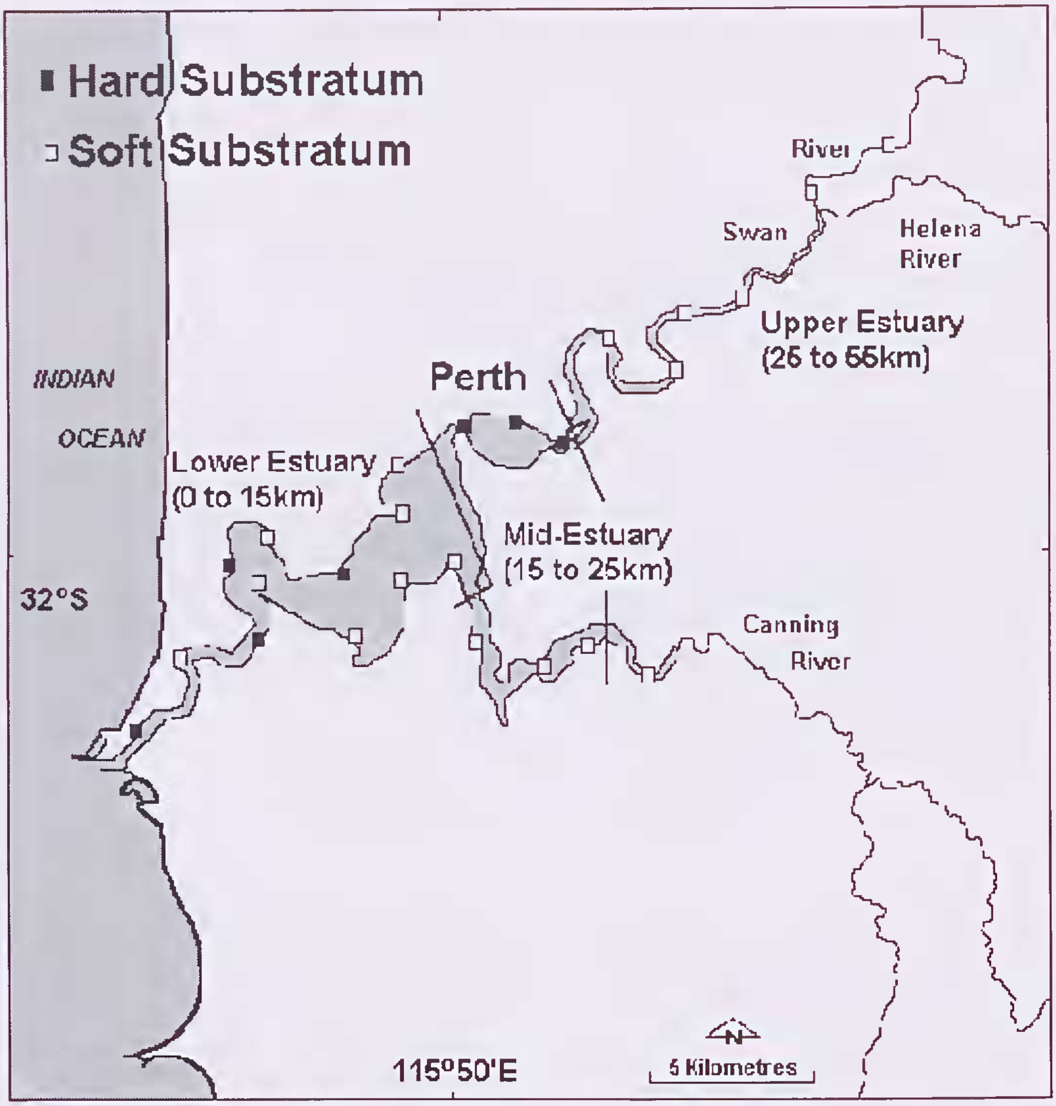

Figure 1. Location of macroalgal sampling sites (indicating hard or soft substrate), with estuarine region (lower, mid and upper) indicated, in the Swan-Canning Estuary

Materials and Methods

Macroalgal communities were sampled every three months between August 1995 and May 1997 at 28 sampling sites (Fig 1). The area of each site was approximately 50 m^2, and they were located near the banks of the estuary where water depths were less than 7 m. Sites were grouped into stratified regions of the system, and categorised as the 'lower reaches' (0 to 15 km upstream from the estuary mouth), the 'mid reaches' (15 to 25 km from the mouth), and the 'upper reaches' (25 to 55 km upstream).

At each site attached macroalgae were sampled using a 0.25 m^2 quadrat, within which all macroalgae were removed by hand. Unattached macroalgae were sampled using a 9.5 cm (id) perspex corer, which was pushed into the sediment over the benthic macroalgae and sealed. The macroalgae were then separated from the underlying sediment with a 2 mm sieve, and placed on ice. Five replicate samples were taken at each site (for both quadrats and cores); ten samples at sites where both attached and unattached macroalgae were present. Macroalgal samples were sorted into species, identified, then dried to a constant dry weight at 70–80 °C. Biomass estimates are means of 5 replicates, expressed as g dry weight.m^{-2} with associated standard errors. Salinity throughout this publication is referred to without units according to the Practical Salinity Scale. On this scale, salinity is defined as a ratio of conductivities and therefore cannot have units.

Analyses of Variance were performed using Statistica for the dependent variables species number and biomass. Post-hoc analyses were performed using the Tukey HSD test. All data were tested for normality and homogeneity of variance prior to analyses; data not normally distributed or with homogeneity of variances was log-transformed prior to analyses.

Results and Discussion

Macroalgal Species

A list of the macroalgal species recorded during the

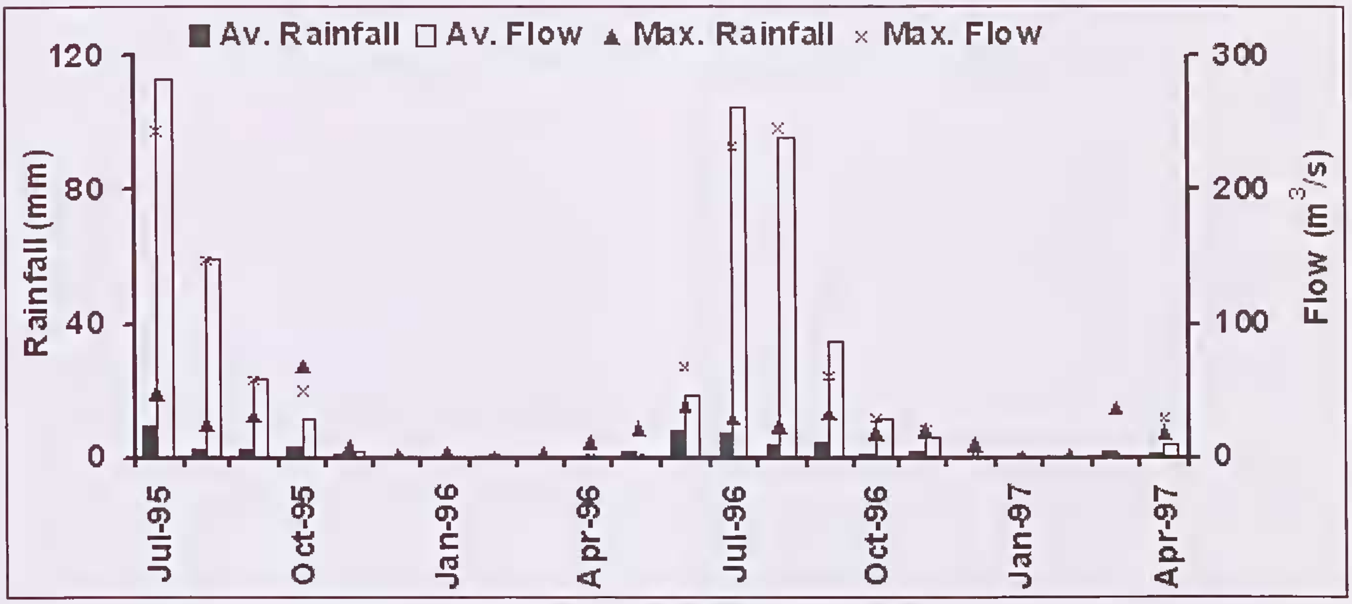

Figure 2. Average (Av.) and maximum (Max.) rainfall (in mm) and river flow (in $m^3.s^{-1}$) recorded for each month between July 1995 and April 1997

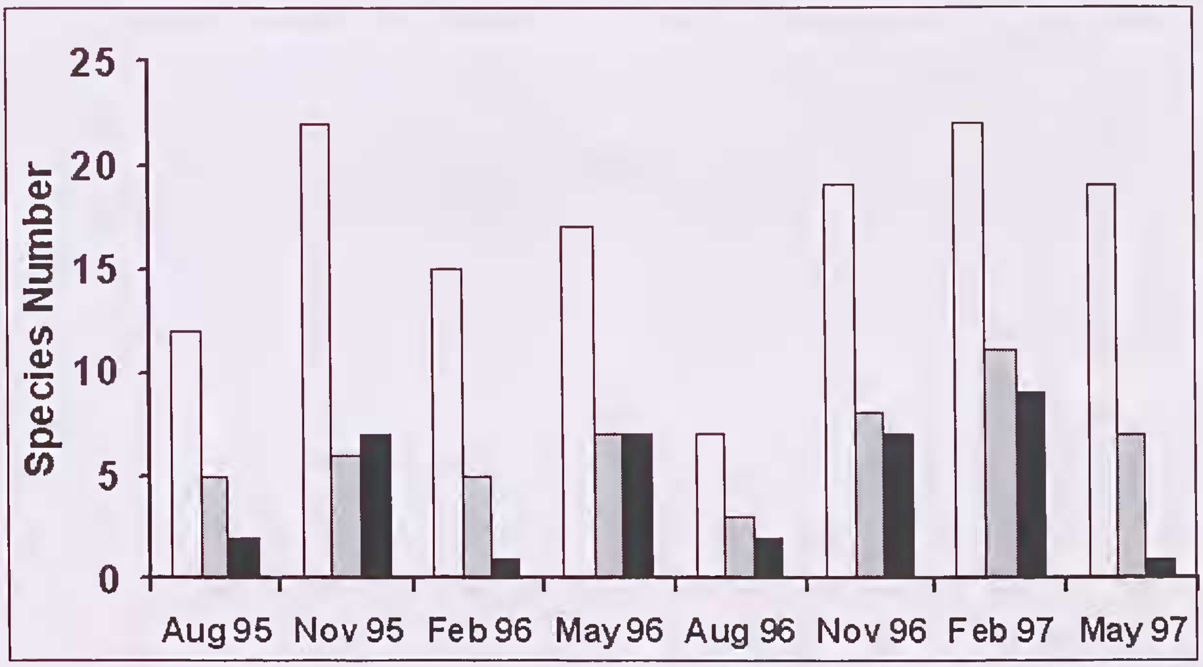

Figure 3. Macroalgal species number at sites within lower (□; 0 to 15 km), mid (■; 15 to 25 km) and upper (■; 25 to 55 km) estuarine reaches of the Swan-Canning Estuary

eight seasonal surveys is provided in Table 1, which includes the season in which each species was found. In total, 36 species of macroalgae were recorded during the study, dominated by chlorophytes (20 species) and rhodophytes (12 species). The highest total species number recorded in any one season was 20 in spring (November 1995) and the lowest was 6 recorded in winter (August 1996), the season of highest rainfall and river flows (Fig 2).

Regionally, the highest total species number was recorded in the lower estuarine reaches (Fig 3), where benthic salinities were over 30 in number in all seasons and macroalgal assemblages were dominated by species common to the nearby marine environment (Huisman 2000). Within this estuarine region, species numbers varied between 15 and 22 in spring, summer, and autumn, falling to between 7 and 12 in winter. The total species number was significantly lower in mid- and upper-estuarine reaches (Tables 2 and 3). In total, between 6 and 11 species were found in the mid-estuarine regions of the estuary in all seasons except winter (3–5 species), while in the upper reaches 7 to 9 species were recorded, although lower numbers of 1 to 2 species were found in winter. An exception to this generally low species number in the upper estuarine reaches was in November 1996 when 7 species were found in this estuarine region.

The total number of macroalgal species found during these surveys was 36, with the highest number recorded in any one season (spring) being 20 (Tables 2 and 3). These species numbers indicate a relatively diverse macroalgal community compared to other south-western Australian estuaries. For example, Hillman *et al.* (2000) listed only 13 macroalgal species from multiple surveys of the Leschenault Inlet between 1984 and 1993. The Leschenault Inlet also receives freshwater input from two rivers, the Collie and Preston Rivers, with an artificial connection to the ocean. Since construction of the Wellington Dam on the Collie River, freshwater input to the system has been significantly reduced, causing salinities within the Inlet to be marine throughout most of the year, and hypersaline in the northern end of the system. As reported here for the Swan-Canning System, the macroalgal assemblages in Leschenault Inlet were co-dominated by rhodophytes and chlorophytes, with the predominant species being *Gracilaria* sp and *Chaetomorpha linum*, respectively. Similarly, Lukatelich *et al.* (1984) recorded 8 macroalgal species in Wilson Inlet, primarily chlorophytes. In contrast, Phillips & Lavery (1997) found 40 macroalgal species in Waychinicup Estuary, dominated by phaeophytes and rhodophytes. Waychinicup Estuary is a small system (1.3 km in length) that has a strong tidal influence with a small, but consistent freshwater input. These hydrodynamic characteristics result in both vertical and horizontal variations in salinity within the estuary, with surface salinities at the head of the estuary as low as 22, and salinities at the mouth of the estuary effectively marine (34). As found in the current survey of the Swan-Canning Estuary, it was also in the lower reaches of Waychinicup Estuary, where extensive hard substratum is present, that most of opportunistic macroalgal species recorded during the investigation were recorded.

Allender (1981) first reviewed the macroalgal species of the Swan-Canning Estuary in 1968 over a one-year period. Allender surveyed benthic macroalgal communities present in the photic zone within the lower 25 km of the system. In total, he recorded 29 species comprising 11 chlorophytes and 14 rhodophytes, the majority of which he recognised as marine. As such, he proposed that the distribution of macroalgae along the horizontal axis of the estuary was strongly affected by the penetration of marine waters and the physiological tolerance of these species to freshwater inflows during winter. Accordingly, he found that the maximum horizontal distribution of species was during summer and the minimum was during winter. Allender (1981) proposed that macroalgal species in the Swan-Canning Estuary could be categorised as either annuals or perennials, depending upon whether the plants survived the winter season, and concluded that seasonal and temporal patterns in macroalgal communities of the system were largely due to the penetration and duration of marine waters into the estuary.

The present study provided preliminary identification of spatial and temporal patterns present in the macroalgal assemblages of the Swan-Canning Estuary, evidenced by the presence and absence of individual species according to season and estuarine region. In particular, highest species numbers were encountered in summer and autumn in the lower estuarine region, areas and times of high salinity and hard limestone substrate. Outside of these seasons and region, the number of macroalgal species was far fewer, mostly unattached macroalgae growing over soft sediments dominated by the species *Gracilaria comosa*.

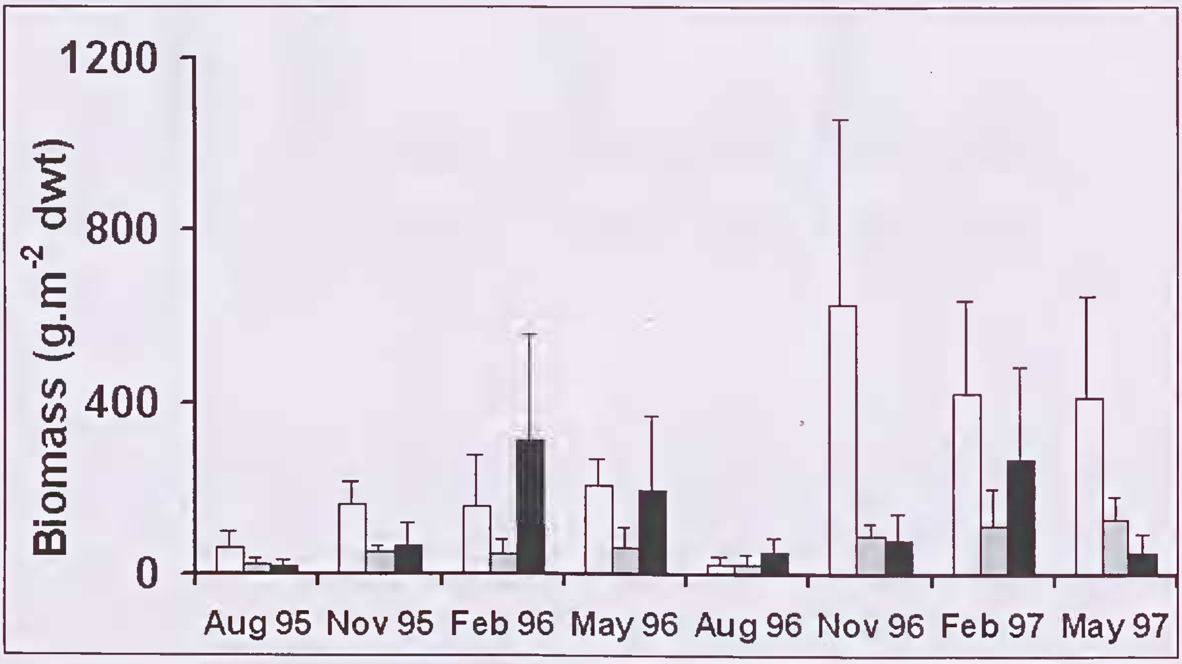

Figure 4. Macroalgal species number at (a) hard and (b) soft substrate sites within lower (□; 0 to 15 km), mid (▒; 15 to 25 km) and upper (■; 25 to 55 km) estuarine reaches of the Swan-Canning Estuary

G. comosa was found in all surveyed regions of the system on all sampling occasions, indicating that this species is euryhaline, tolerating osmotic change resulting from the advent of winter freshwater pulses. However, given that the species forms large unattached accumulations, the physical force of freshwater pulses results in the removal of *G. comosa* accumulations and therefore the disappearance of this species from many areas of the system during winter (Astill & Lavery 2001). Therefore, in addition to any physiological influence that freshwater pulses have on invasive marine species colonising lower estuarine reaches, such freshwater pulses have a physical influence on unattached species in the mid- and upper-estuarine reaches. Thus, it appears that the advent of freshwater pulses to the system in winter has a considerable effect, both physiological and physical, on benthic macroalgal assemblages throughout the estuary.

Macroalgal Biomass

The distribution and quantity of macroalgal biomass in the estuary was very patchy (Fig 4). Mean macroalgal biomass ranged between 18 and 629 $g.m^{-2}$ dwt, varying according to estuarine region and season. Regionally, the highest mean biomass (629 $g.m^{-2}$ dwt) was in the lower estuarine reaches, the combined result of *Cystoseira trinodis* stands and *Gracilaria comosa* accumulations. Mean macroalgal biomass in the mid- and upper-reaches was highly variable, ranging between 24 - 130 g/m^2 dwt and 18 - 314 $g.m^{-2}$ dwt, respectively. Seasonally, the highest mean biomass during the survey, 629 $g.m^{-2}$ dwt, was in spring, and the lowest (18 $g.m^{-2}$ dwt) was in winter.

Macroalgal biomass was generally dominated by rhodophytes, although macroalgae of the division Chlorophyta dominated at times in mid- and upper-

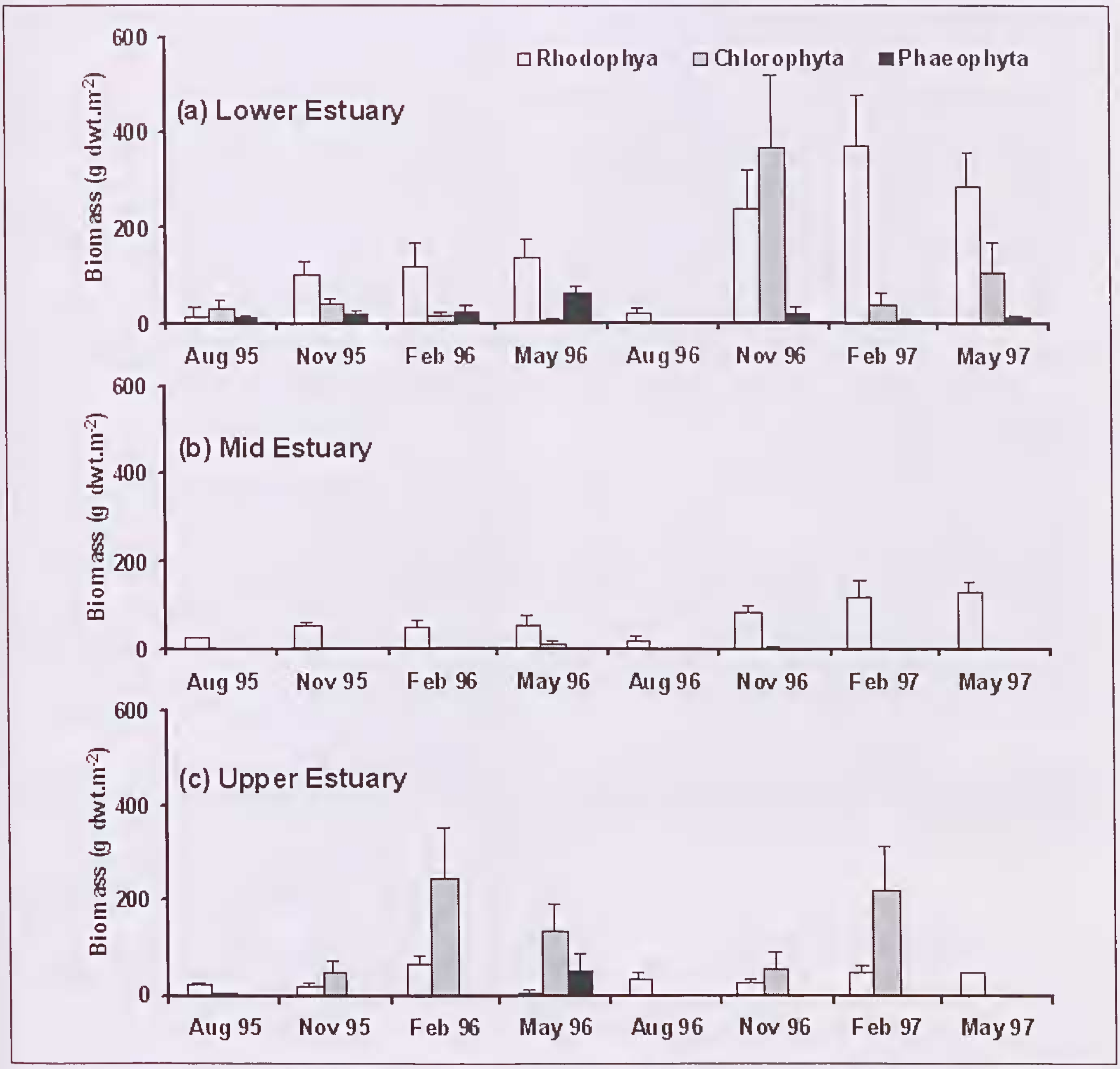

Figure 5 Mean macroalgal biomass at sites within lower (□; 0 to 15 km), mid (▒; 15 to 25 km) and upper (■; 25 to 55 km) estuarine reaches of the Swan-Canning Estuary (± SE)

estuarine reaches (Fig 5). A large proportion of the macroalgal biomass was attributable to *Gracilaria comosa*. In winter, this species constituted over 90% of the total macroalgal biomass at the sampling sites, especially at those lacking hard substrate (*i.e.* predominantly mid- and upper-estuarine reaches). At freshwater-dominated sites in the upper region, a loose-rubble substratum was present and macroalgal biomass at these sites was dominated by the freshwater chlorophyte, *Chara* sp.

Biomass measurements in Leschenault Inlet showed a similar seasonal variation in macroalgal biomass, varying between 46 g/m^2 dwt in autumn/winter to 209 g/m^2 dwt in spring (Hillman *et al*. 2000). Macroalgal biomass in the Leschenault Inlet was dominated by chlorophyte and rhodophyte species (11 to 43% of total biomass, and 20 to 30% during spring, respectively). Similarly, in Peel Inlet, minimum and maximum macroalgal biomasses of 25 g/m^2 dwt (November 1988) and 237 g/m^2 dwt (April 1993) were recorded, although this biomass was predominantly (>85%) composed of chlorophyte species (Hillman *et al*. 2000).

Previous studies have attributed seasonal variability in macroalgal biomass to factors such as changes in light and nutrient availability (Kinney & Roman 1998; Collado-Vides 1994; King & Schramm 1976), while studies on drift macroalgae attribute a proportion of seasonal variation in biomass to water movement (Talbot *et al*. 1990; Virnstein & Carbonara 1985). Bell & Hall (1997) found drift macroalgal biomass in Tampa Bay (USA) to vary between almost nothing to more than 150 g/m^2 dwt. They suggested that variations in macroalgal biomass and distribution were related to local hydrodynamic regimes, such as wave action, currents, wind and tides.

In this study, *G. comosa* was commonly found in large, unattached accumulations overlying soft sediment, dominating macroalgal biomass in the system. However, this species was noticeably reduced or absent with the onset of winter freshwater flows, resulting in subsequent reductions in total macroalgal biomass throughout the system. From these observations it is proposed that seasonal freshwater flows in the system strongly affect the presence/absence of unattached macroalgal species through both physical and physiological means, and the quantity of macroalgal biomass present. Winter freshwater flows appear to be a dominant environmental factor controlling the presence, diversity and abundance of macroalgal assemblages in the Swan-Canning Estuary.

Acknowledgements: The assistance of M Pennifold in the field and of M Vanderklift in the laboratory, is gratefully acknowledged. The authors also thankfully acknowledge A. McComb's advice on the manuscript. Financial assistance was provided by the Western Australian Estuarine Research Foundation.

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